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Kimura et al.

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(54) **PISTON TYPE COMPRESSOR HAVING SUCTION STRUCTURE WITH ARCUATELY SHAPED SUCTION VALVE**

(75) Inventors: **Naofumi Kimura**, Kariya (JP); **Masakazu Obayashi**, Kariya (JP)

(73) Assignee: **Kabushiki Kaisha Toyoda Jidoshokki Seisakusho**, Kariya (JP)

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(52) **U.S. Cl.** **417/222.1**; 417/269; 417/571; 417/569; 137/856

(58) **Field of Search** 417/222.1, 222.2, 417/269, 571, 569; 137/856, 855

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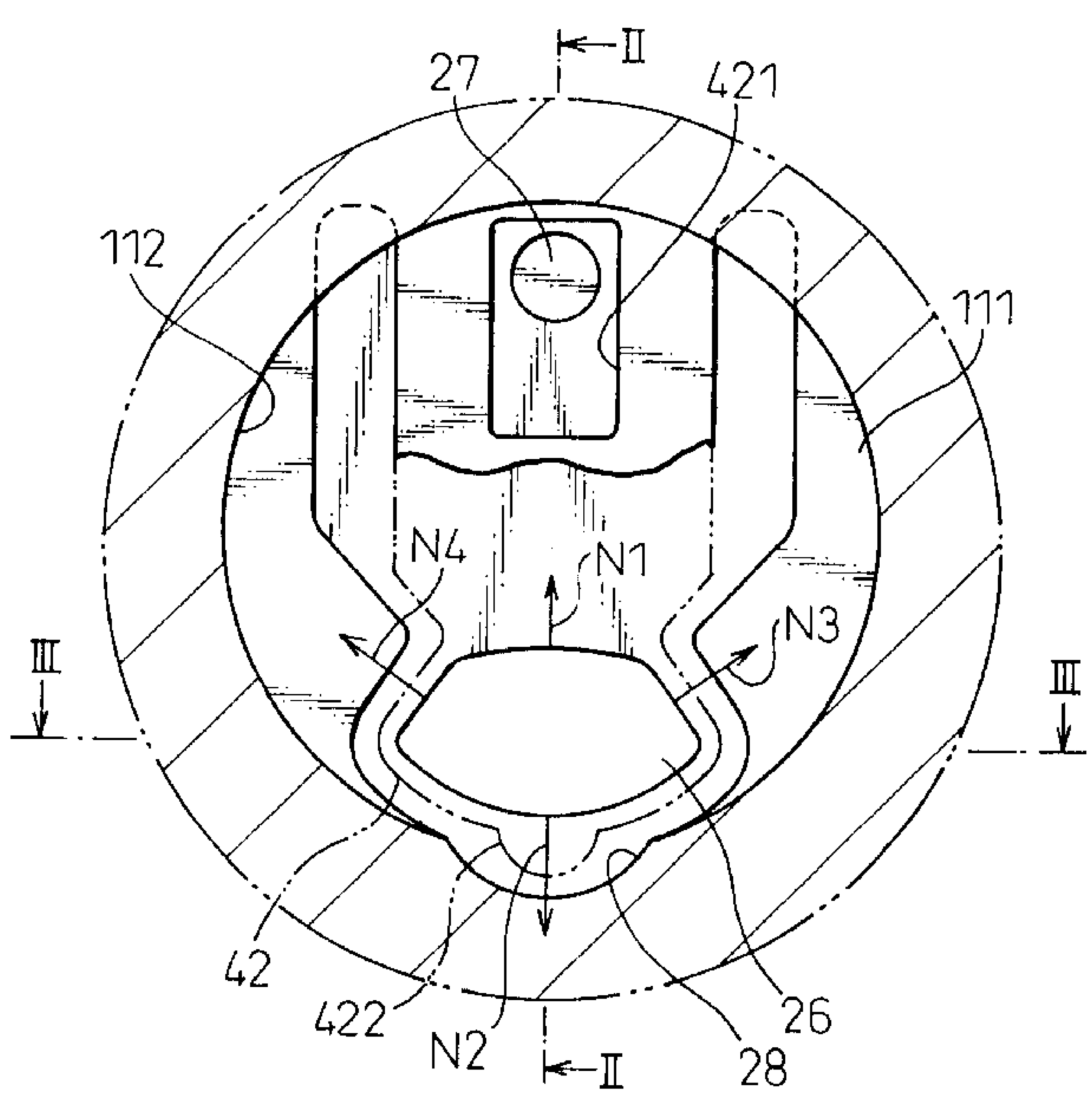
Primary Examiner—Charles G. Freay
Assistant Examiner—Michael K. Gray
(74) *Attorney, Agent, or Firm*—Woodcock Washburn LLP

(57) **ABSTRACT**

A suction port of a piston type compressor is formed in the shape similar to a portion of a sector with an apex portion of the sector removed. A distal end portion of a suction valve which can open and close the suction port has a contour line including a distal end forming line extending generally parallel to a distal end line of the suction port, and side lines. A gap between the distal end line of the suction port and the distal end forming line of the suction valve is substantially constant, and a gap between the distal end forming line and the circle of the cylinder bore is substantially constant. The ease of the inflow of a gas when the gas is sucked from the suction port to the cylinder bore is improved.

10 Claims, 10 Drawing Sheets



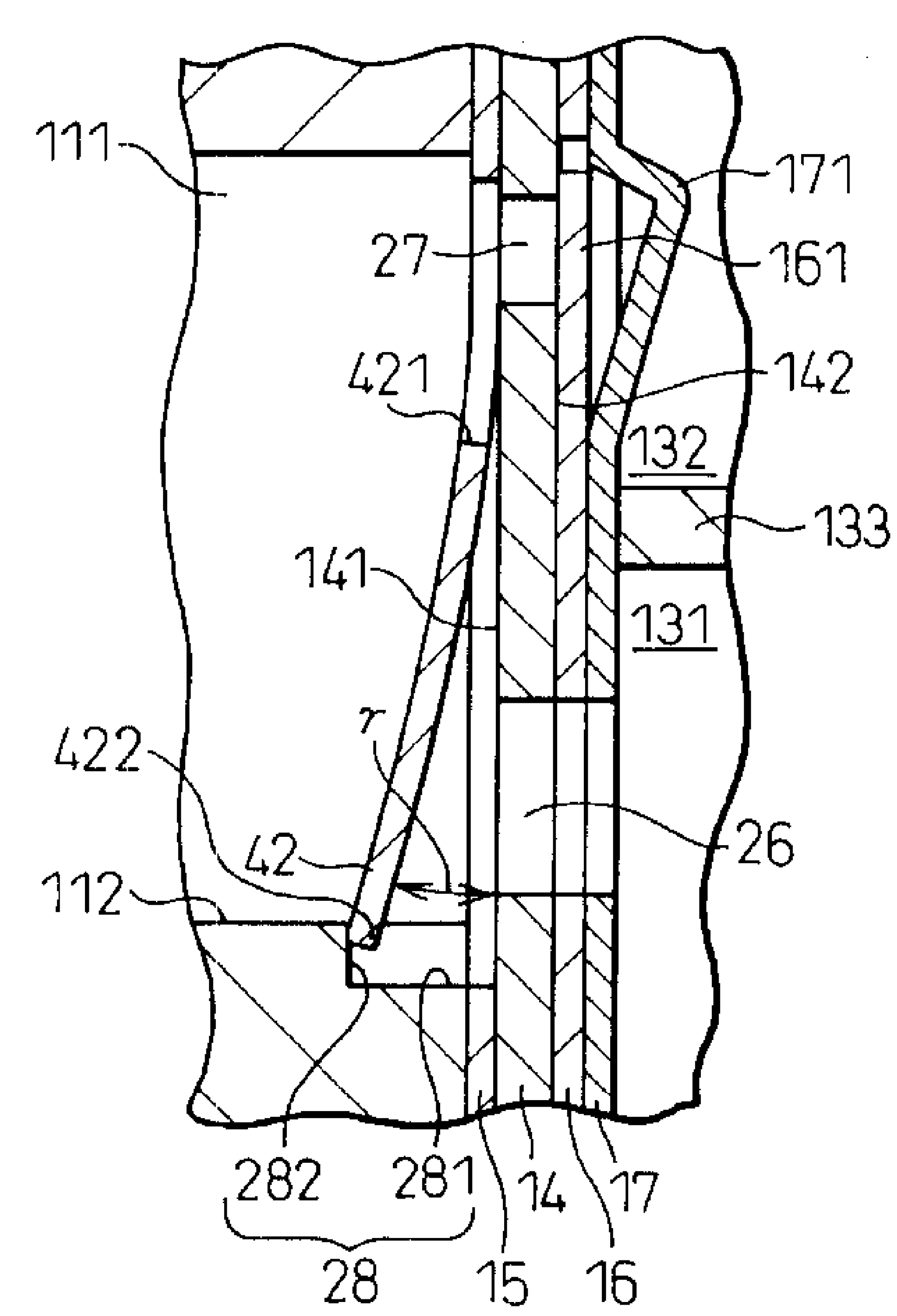
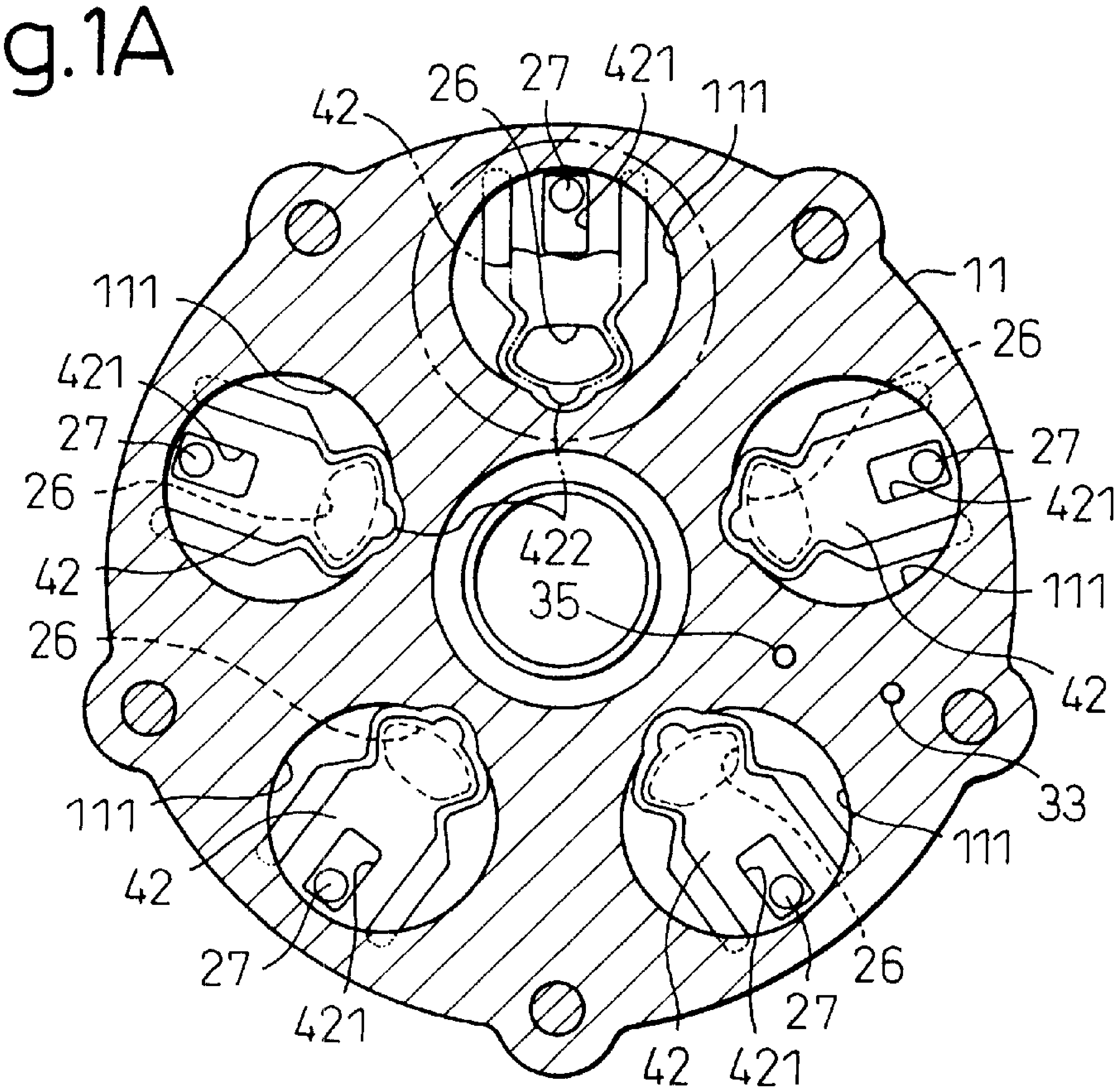


Fig.1A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111
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421
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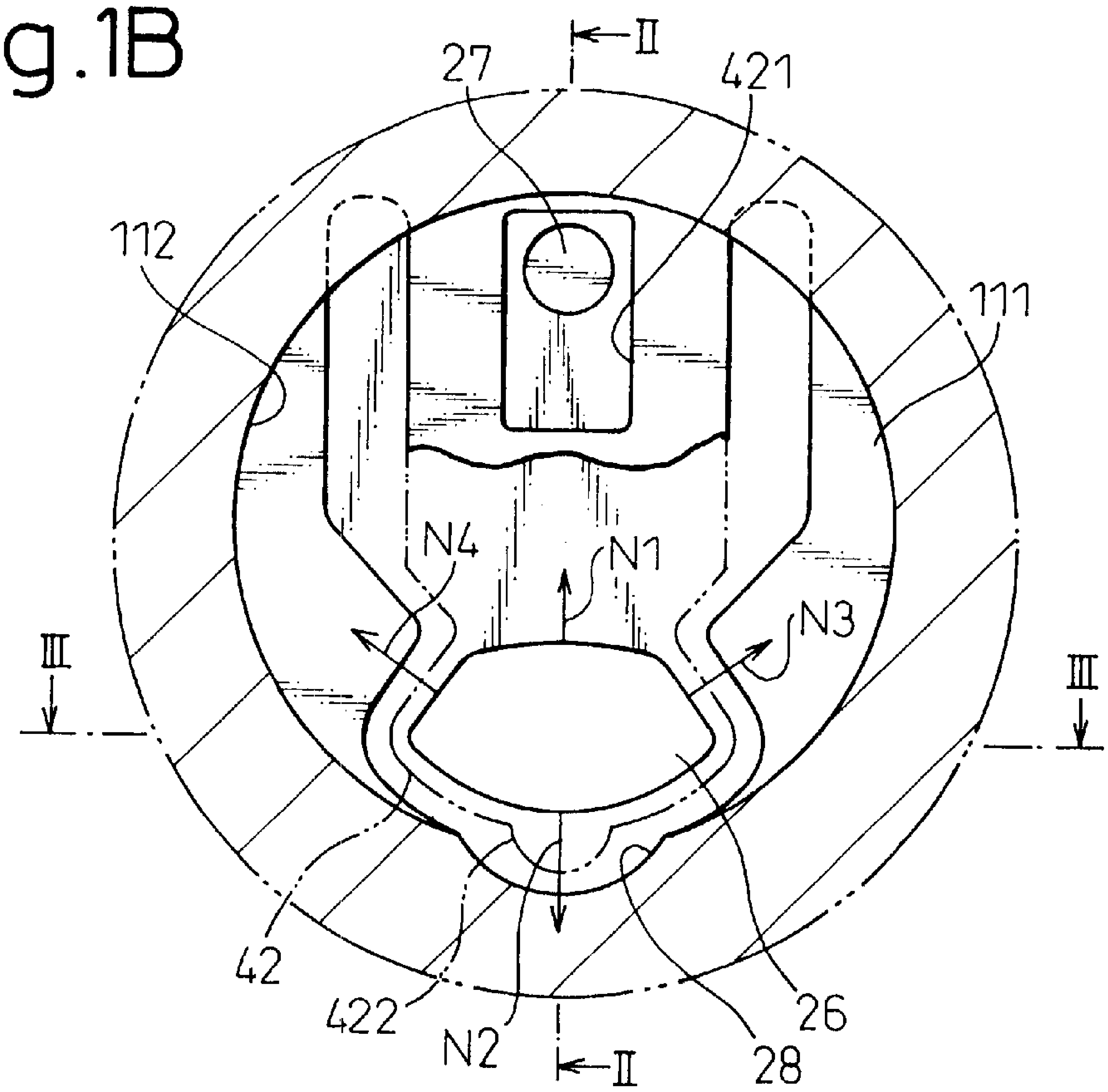
42
421

Fig.1B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421
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111
N4
N1
N3
III
III
42
422
N2
II
28
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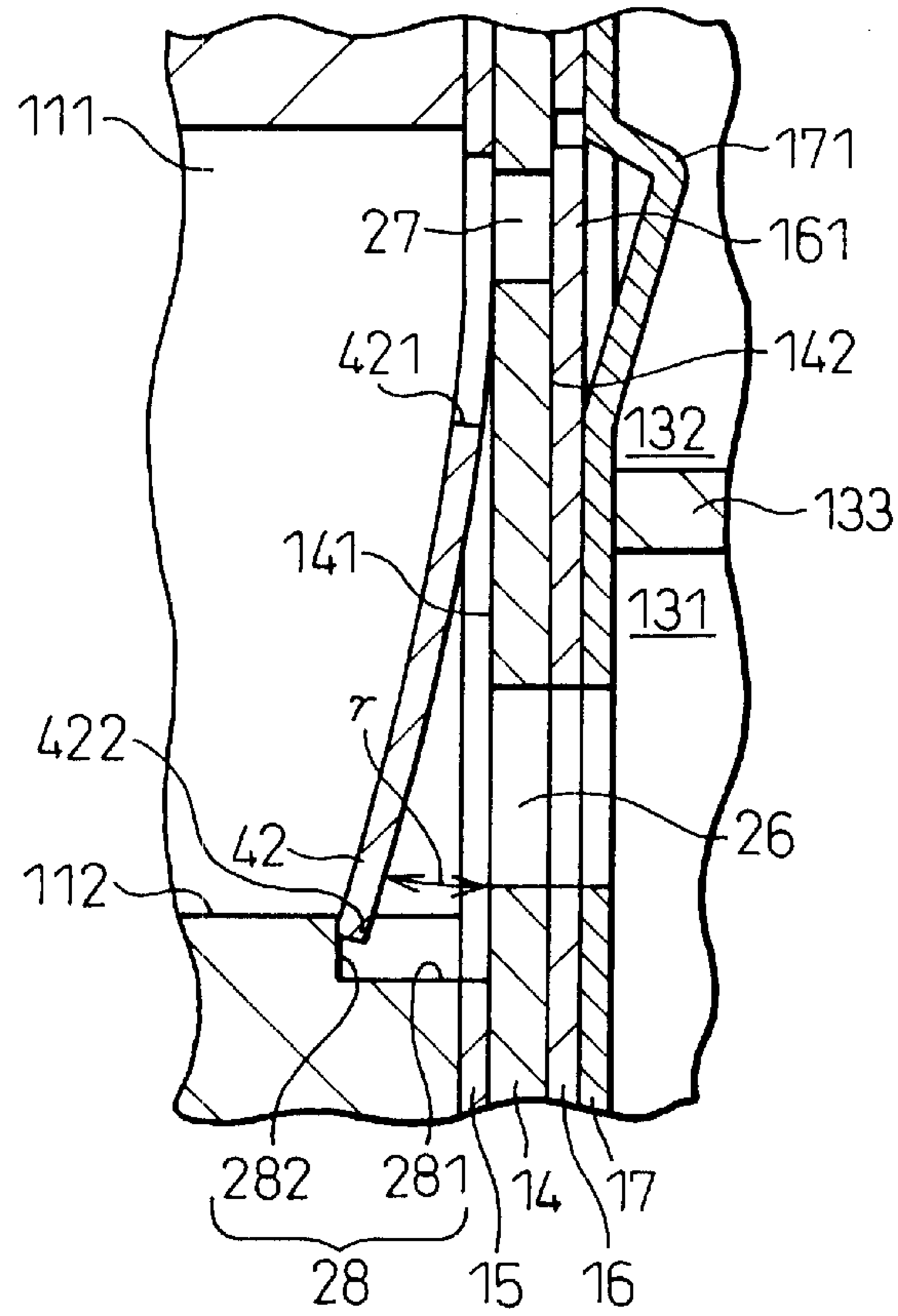
Fig.2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27
421
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422
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112
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171
161
142
132
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282
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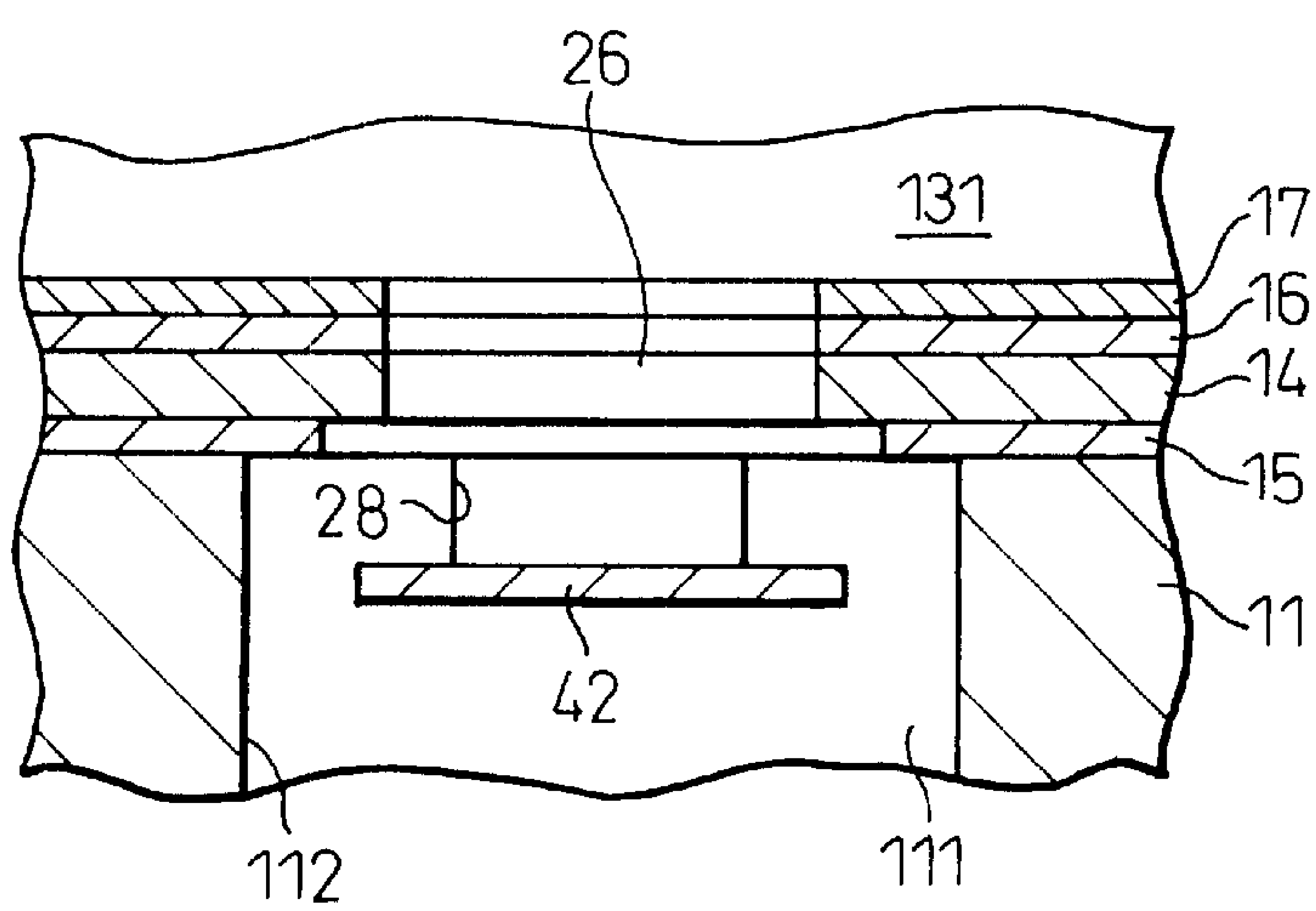
28
15
14
16
17

Fig.3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131
17
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14
15
28
42
11
112
111

Fig.4

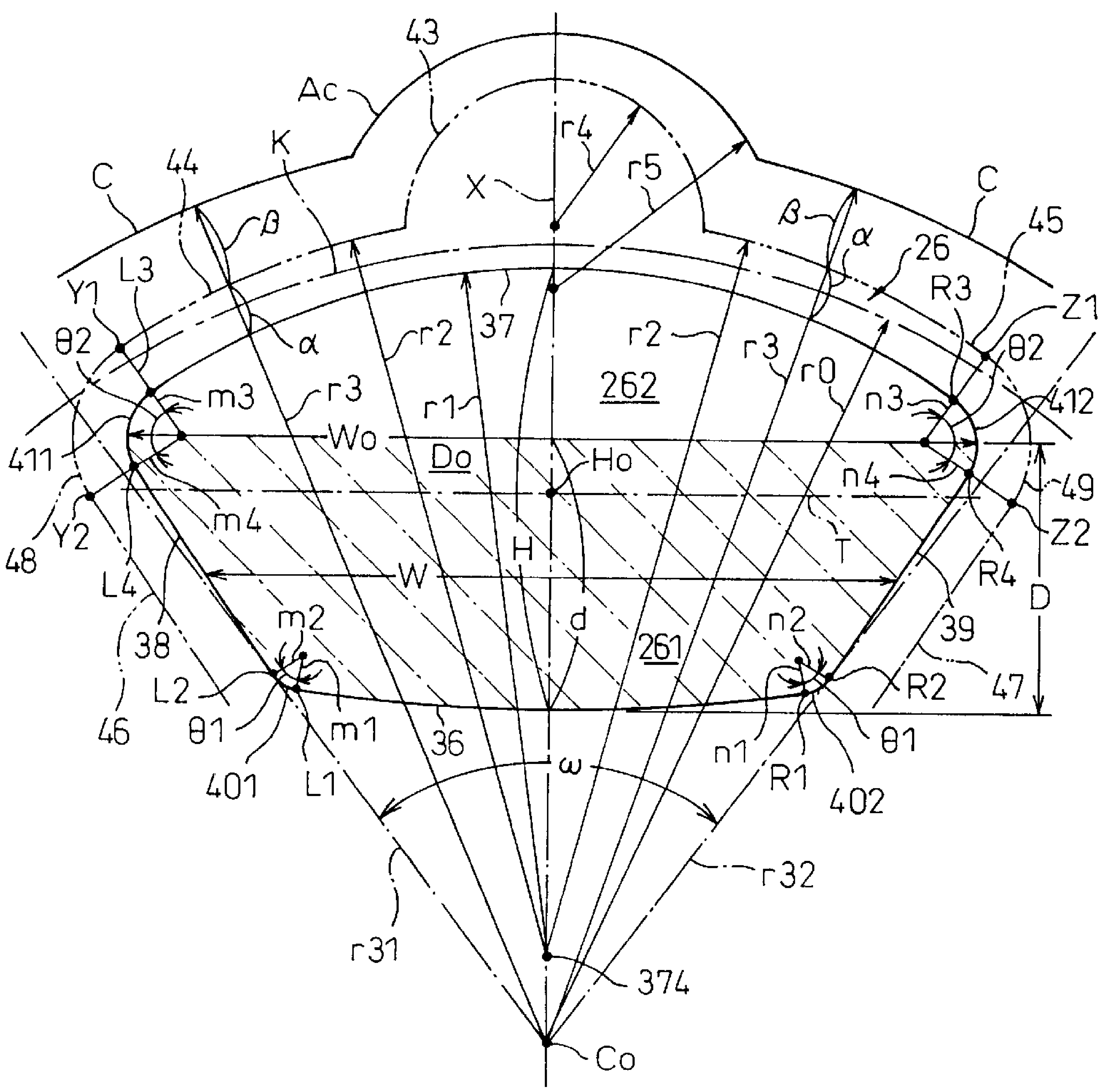
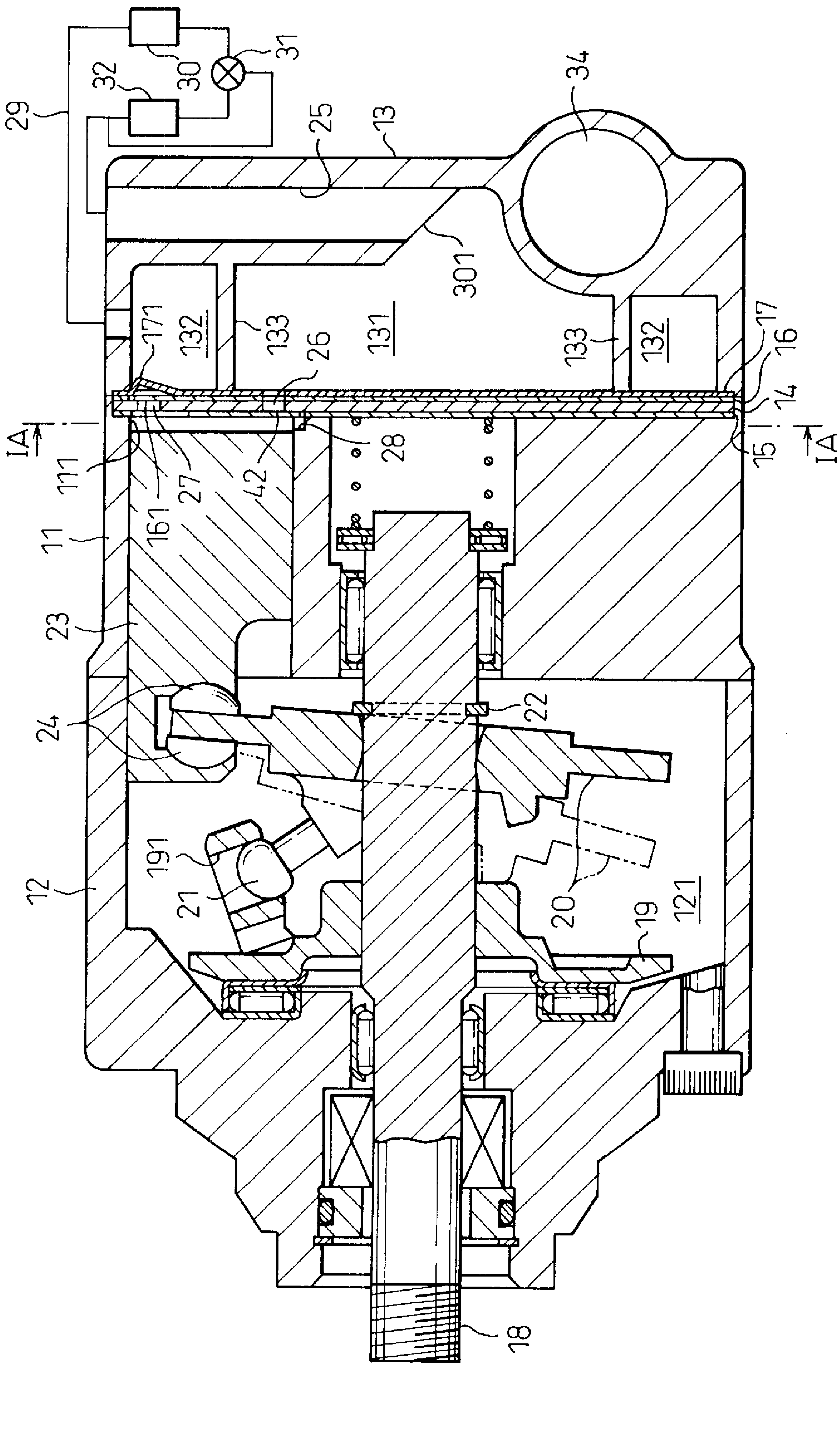


Fig.5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131
133
132
17
16
14
IA
111
161
27
42
28
15
IA
11
23
24
22
191
21
12
20
121
19
18

Fig.6A

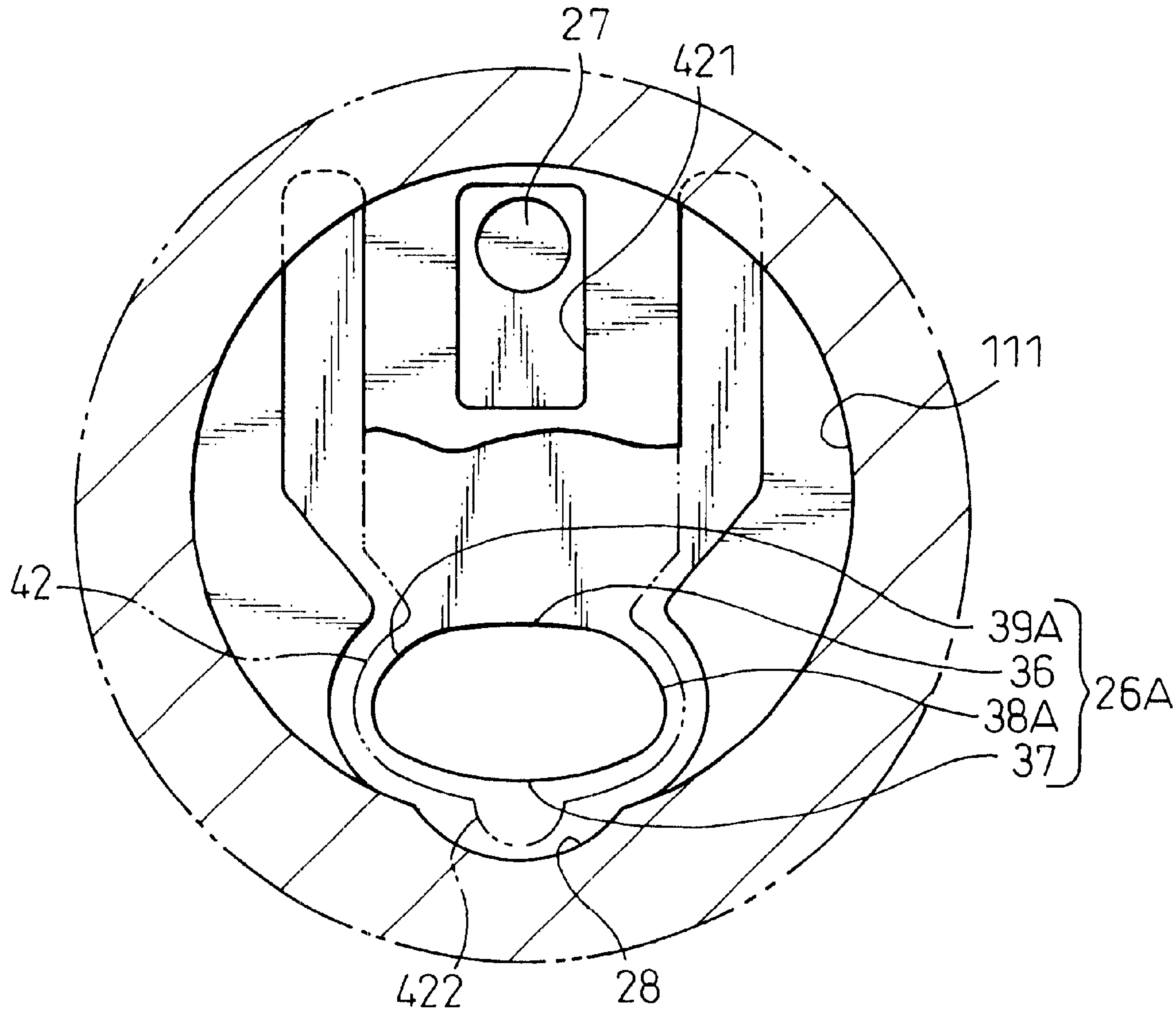
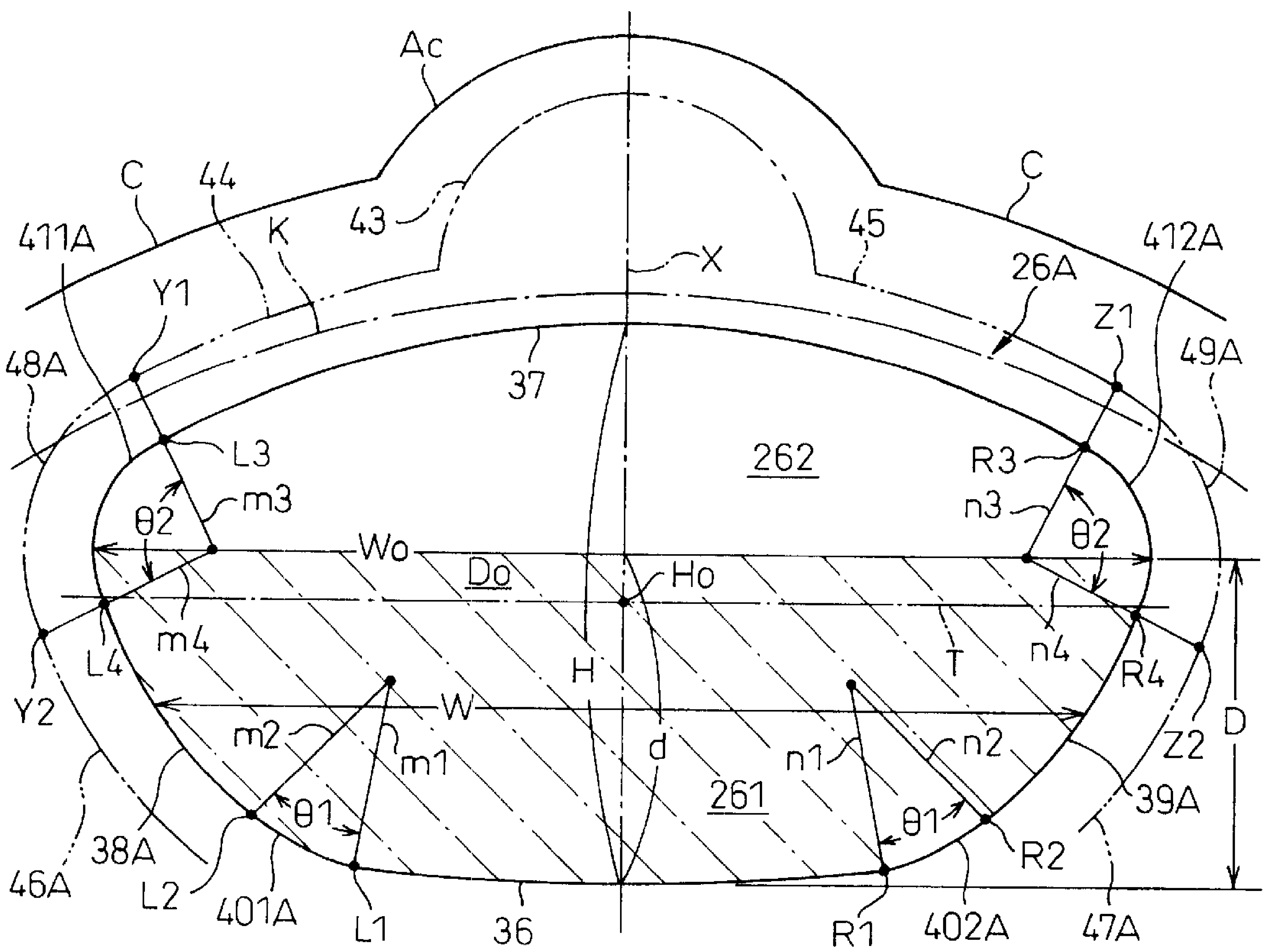


Fig.6B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θ2
θ2
Wo
Do
Ho
m4
n4
L4
T
R4
Y2
H
W
Z2
D
m2
m1
d
n1
n2
θ1
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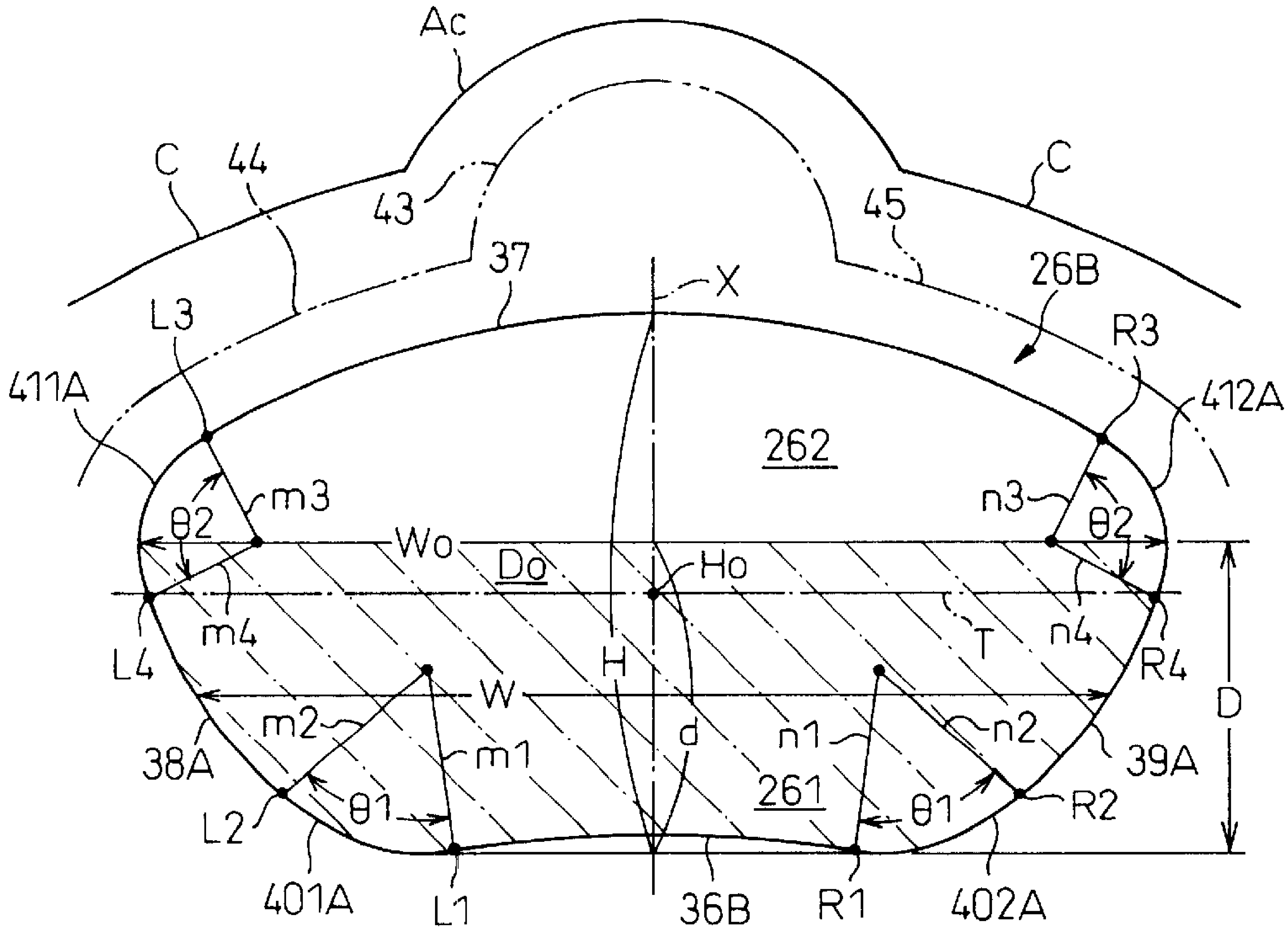
θ1
39A
R2
38A
46A
L2
401A
L1
36
R1
402A
47A

Fig.7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D
m2
n2
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θ1
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R2
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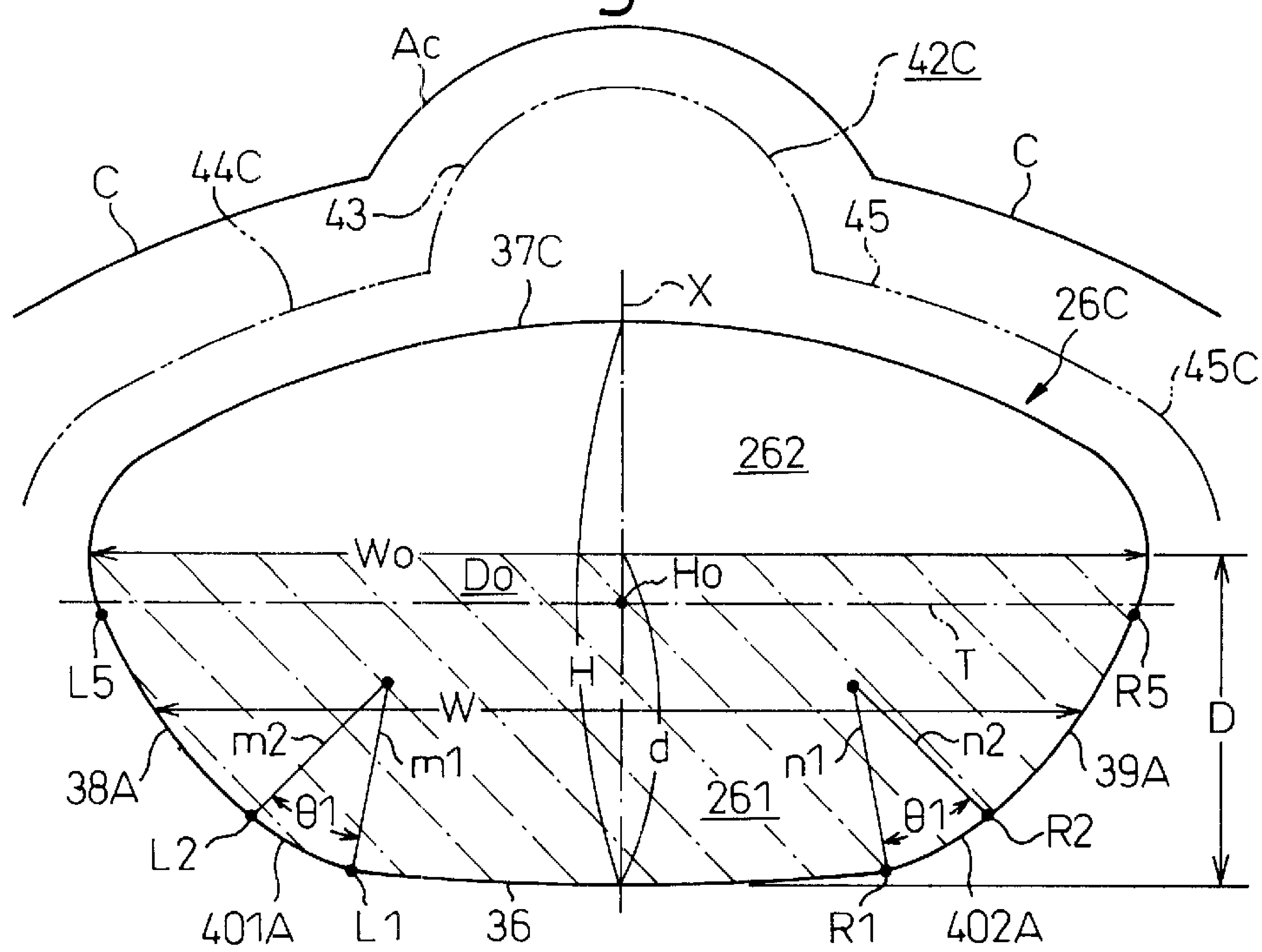
R1
402A

Fig.8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D
m2
n2
m1
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261
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401A
L1
36
R1
402A

Fig.9

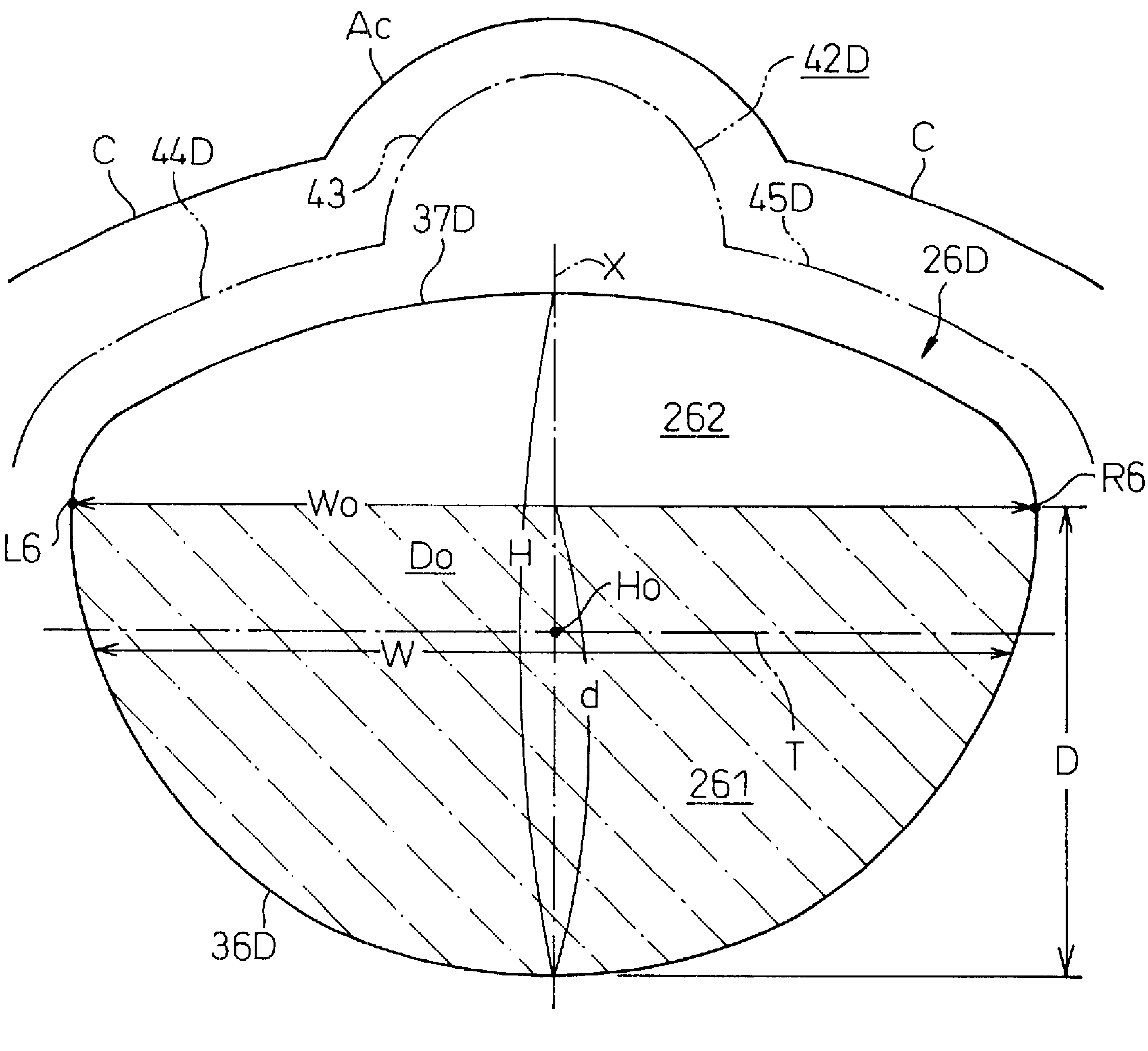

Fig.10

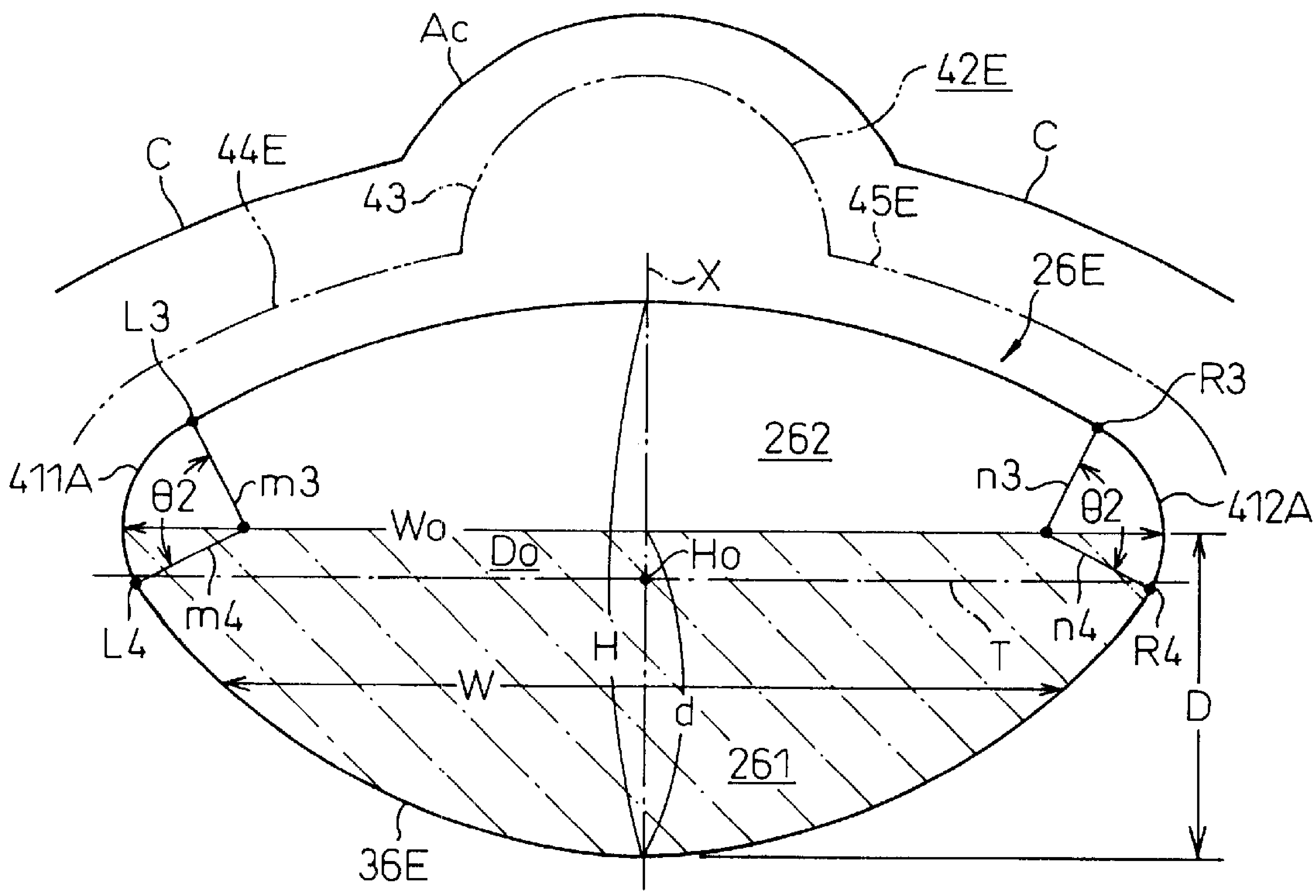
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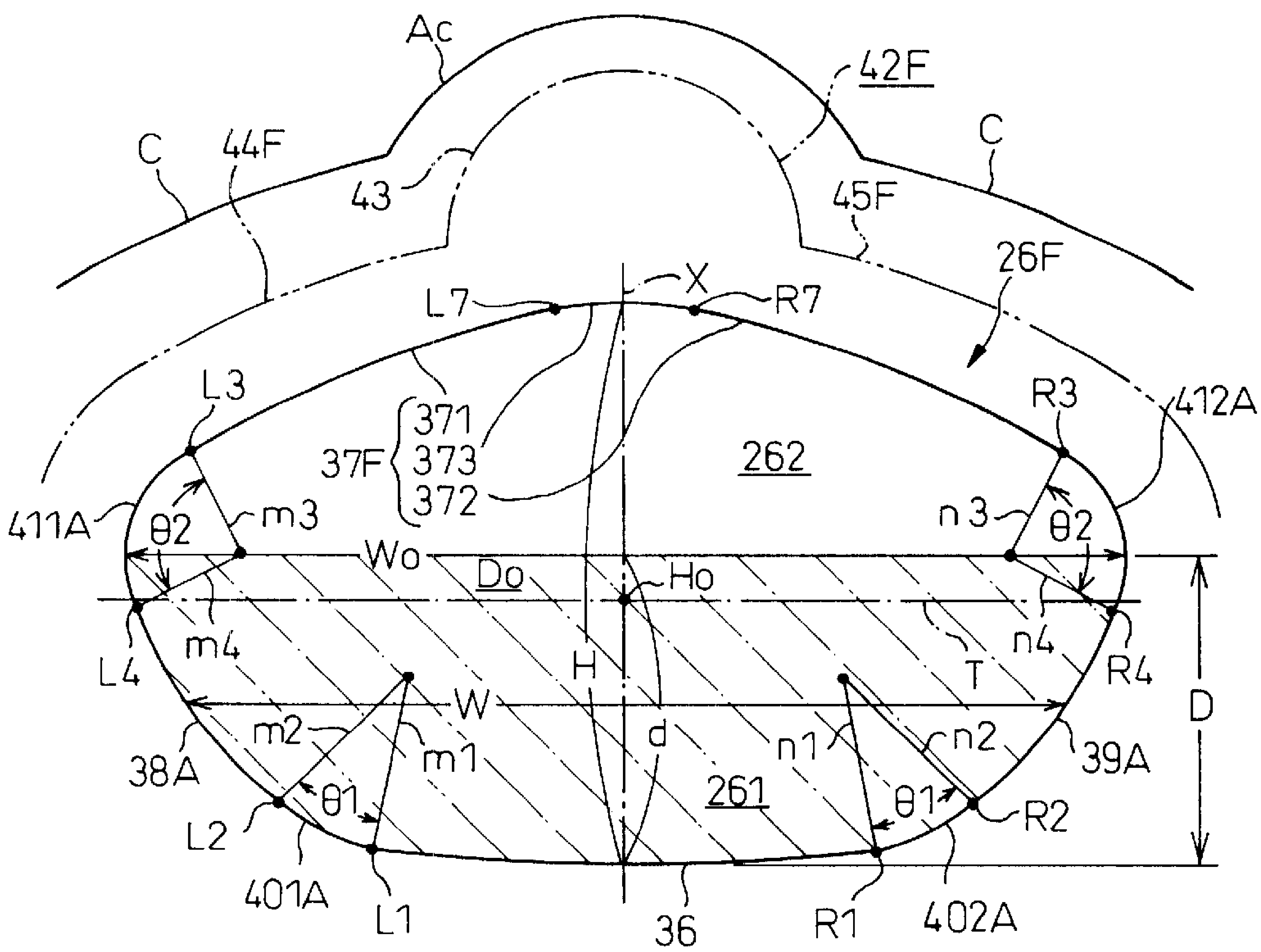
Fig.11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38A
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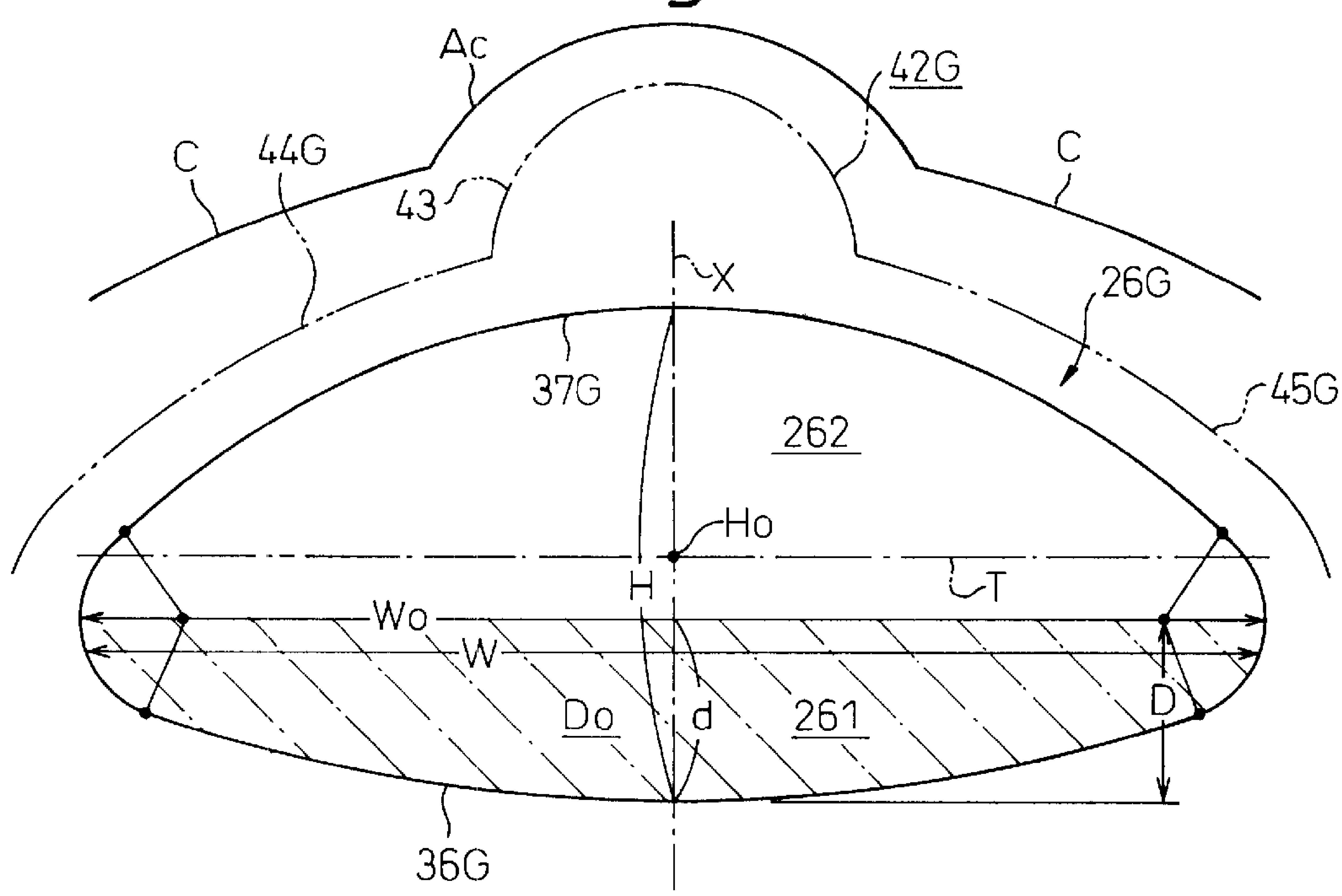
402A

Fig.12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36G

PISTON TYPE COMPRESSOR HAVING SUCTION STRUCTURE WITH ARCUATELY SHAPED SUCTION VALVE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a piston type compressor having a suction structure with a suction valve, capable of flexural deformation for opening and closing a suction port, for sucking a gas from the suction port into a cylinder bore, by pushing the suction valve to open under a sucking operation of each piston in the cylinder bore.

2. Description of the Related Art

When a gas is sucked from a suction chamber into a cylinder bore in a piston type compressor, the facility or ease of the inflow of the gas greatly affects volumetric efficiency.

A suction port disclosed in Japanese Unexamined Patent Publication (Kokai) No. 57-97974 is circular and a suction port disclosed in Japanese Unexamined Patent Publication (Kokai) No. 2000-54961 is somewhat rounded and substantially triangular. A gas passing through the suction port from a suction chamber towards a cylinder bore exclusively flows in a direction perpendicular to a contour line of the suction port, as viewed from the reciprocating direction of a piston, (the circular port in Japanese Unexamined Patent Publication (Kokai) No. 57-97974 and the rounded triangular port in No. 2000-54961) and enters the cylinder bore. The opening gap of the suction valve relative to the valve plate becomes progressively greater towards the distal end of the suction valve. It is therefore effective to let the gas passing through the suction port flow in the longitudinal direction of the suction valve from its distal end side in order to improve facility of the inflow of the gas. The gas passing through the suction port exclusively flows in the direction perpendicular to the contour line that forms the hole of the suction port. Therefore, it can be said in connection with the contour line of the suction port that the greater the length of the contour on the distal end side of the suction valve, the easier it becomes for the gas to flow towards the distal end side of the suction valve. The suction port described in Japanese Unexamined Patent Publication (Kokai) No. 2000-54961 is superior to the circular suction port described in Japanese Unexamined Patent Publication (Kokai) No. 57-97974 because the gas passing through the suction port can flow more easily from the distal end side of the suction valve in its longitudinal direction in the former than in the latter. Therefore, the ease of the inflow of the gas is higher in the suction port of Japanese Unexamined Patent Publication (Kokai) No. 2000-54961 than in the circular suction port of the Japanese Unexamined Patent Publication (Kokai) No. 57-97974.

The position of the suction port in the circle of the circumferential surface of the cylinder bore as viewed in the reciprocating direction of the piston is close to a circumferential line of the circle of the cylinder bore, based on the relationship with the discharge port. In the contour line of the suction port described in Japanese Unexamined Patent Publication (Kokai) No. 2000-54961, a portion of the contour line close to the circumferential line of the circle of the cylinder bore is spaced apart, progressively, from the circumferential line of the circle of the cylinder bore as it extends away to the right and left from the center line of the suction port (represented by X in the drawing). The degree of separation is smaller, in comparison, than in the case of the circular suction port. The gas can more easily flow from the distal end side of the suction valve in its longitudinal direction in the suction port described in Japanese Unexamined Patent Publication (Kokai) No. 2000-54961 than in the circular suction port. Therefore, as to ease of the inflow of the gas, the suction port of Japanese Unexamined Patent Publication (Kokai) No. 2000-54961 is superior to the circular suction port of Japanese Unexamined Patent Publication (Kokai) No. 57-97974.

The construction in which the portion of the contour line close to the circumferential line of the circle of the cylinder bore is spaced apart progressively to the right and left from the center line of the suction valve makes it easy for the gas flowing in a direction crossing the portion of the contour line close to the circumferential line of the circle of the cylinder bore to flow in the direction of the circumferential line of the circle of the cylinder bore. However, such a flow of the gas is not desirable from the aspect of the ease of the inflow of the gas into the cylinder bore.

SUMMARY OF THE INVENTION

The object of the present invention is to provide a piston type compressor which can improve the ease of the inflow of the gas when the gas is sucked from the suction port to the cylinder bore.

To accomplish this object, the present invention provides a piston type compressor comprising a housing having cylinder bores, a suction chamber, a discharge chamber, suction ports and discharge ports formed therein, pistons reciprocatingly arranged in the cylinder bores, a drive shaft rotatably supported by the housing, a transmission mechanism operatively coupled to the drive shaft and the pistons for converting rotation of the drive shaft into reciprocal movement of the pistons, suction valves to open and close the suction ports, and discharge valves to open and close the discharge ports. The suction valve has a proximal end portion and a distal end portion on the opposite side of the proximal end portion, the distal end portion of the suction valve having an outer contour line including a distal end forming line located near a circumferential surface of the cylinder bore and side lines located on either side of the distal end forming line, the suction port having a contour line including a distal end line located near the circumferential surface of the cylinder bore and side lines located on either side of the distal end line. The distal end forming line of the suction valve and the distal end line of the suction port are arranged along the circumferential surface of the cylinder bore, so that a gap between the distal end forming line and the distal end line with respect to a radial line of a circle forming the circumferential surface of the cylinder bore is substantially constant and a gap between the distal end forming line and the circumferential surface of the cylinder bore with respect to the radial line is substantially constant.

The construction in which the gap between the distal end forming line of the suction valve and the distal end line of the suction port and the gap between the distal end forming line and the circumferential surface of the cylinder bore are substantially constant makes it easier for the gas to flow between the circumferential surface of the cylinder bore and the distal end forming line of the suction valve in a returning direction of the piston. Such a gas flow is desirable for improving ease of the inflow of the gas into the cylinder bore.

Preferably, an average of the gap between the circumferential surface of the cylinder bore and the outer end forming line of the suction valve is greater than a gap between the suction valve and the distal end line of the suction port under a maximum valve open condition.

The gas that flows between the suction valve and the distal end line of the suction port so as to perpendicularly impinge against the circumferential surface of the cylinder bore can more easily flow between the circumferential surface of the cylinder bore and the distal end forming line of the suction valve in the returning direction of the piston.

Preferably, a middle line is provided which passes through a middle point of a maximum length of the suction port in a longitudinal direction of the suction valve, extends transversely with respect to the suction port and crosses a reference line extending in the longitudinal direction of said suction valve, the middle line dividing the suction port into a first section positioned on the side of the proximal end portion of the suction valve and a second section positioned on the side of the distal end of the suction valve, an area of the second section being greater than an area of the first section.

The construction in which the area of the second section is greater than the area of the first section makes it easier for the gas passing through the suction port to flow from the distal end side of the suction valve.

Preferably, a width increasing region is disposed in which the width of the suction port in a direction of the middle line becomes gradually greater from the proximal end side to the distal end side of the suction valve in the longitudinal direction of the suction valve, and the length of the width increasing region in the direction of the reference line occupies a major part of the maximum length of the suction port in the direction of the reference line.

The existence of the width increasing region makes it easier for the gas passing through the suction port to flow towards the distal end side of the suction valve.

Preferably, a maximum width of the suction port in the direction of the middle line exists in the second section and is greater than the maximum length of the suction port in the direction of the reference line.

The construction in which the maximum length of the suction port in the direction of the reference line is smaller than the maximum width of the suction port in the direction of the middle line and the maximum width of the suction port in the direction of the middle line exists on the side of the second section is convenient for increasing the length of the contour line of the suction port on the distal end side of the suction valve.

Preferably, the contour line of the suction port includes a proximal end line positioned on the side of the proximal end of the suction valve, said distal end line and a pair of right and left side lines, and the distal end line is longer than the proximal end line.

The construction wherein the length of the distal end line is greater than that of the proximal end line makes it easier for the gas passing through the section port to flow towards the distal end side of the suction valve.

Preferably, the contour line of the suction port includes a pair of first connection lines connecting the proximal end line to the pair of side lines and a pair of second connection lines connecting the distal end line to the pair of side lines, the pair of first connection lines being smoothly connected to the proximal end line and the pair of said side lines, the pair of second connection lines being smoothly connected to the distal end line and the pair of side lines.

Preferably, the contour line of the suction port is an annular line with no corner. The construction wherein the contour line of the suction port is an annular line with no corner is advantageous for preventing backflow of the gas from the cylinder bore to the suction port.

Preferably, the contour line of the suction port is an annular convex line with no corner.

Preferably, the reference line extends substantially along the radial line of the circle of the circumferential surface of the cylinder bore.

The construction wherein the reference line extends substantially along the radial line of the circle of the circumferential surface of the cylinder bore is advantageous for bringing the contour line of the suction port on the distal end side of the suction valve closer to the circle of the circumferential surface of the cylinder bore.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become more apparent from the following description of the preferred embodiments, with reference to the accompanying drawings, in which:

FIG. **1A** is a sectional view of a compressor according to the first embodiment of the present invention, taken along the line IA—IA in FIG. **5**;

FIG. **1B** is an enlarged sectional view of a portion of FIG. **1A**;

FIG. **2** is a sectional view of the compressor, taken along line II—II in FIG. **1B**;

FIG. **3** is a sectional view of the compressor, taken along the line III—III in FIG. **1B**;

FIG. **4** is an enlarged view of the suction port and the suction valve;

FIG. **5** is a sectional view of a portion of a compressor according to the embodiment of the present invention;

FIG. **6A** is an enlarged sectional view of a compressor according to the second embodiment of the present invention;

FIG. **6B** is an enlarged view of the suction port and suction valve of FIG. **6A**;

FIG. **7** is an enlarged view of the suction port and the suction valve according to the third embodiment;

FIG. **8** is an enlarged view of the suction port and the suction valve according to the fourth embodiment;

FIG. **9** is an enlarged view of the suction port and the suction valve according to the fifth embodiment;

FIG. **10** is an enlarged view of the suction port and the suction valve according to the sixth embodiment;

FIG. **11** is an enlarged view of the suction port and the suction valve according to the seventh embodiment; and

FIG. **12** is an enlarged view of the suction port and the suction valve according to the eighth embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The first embodiment of the present invention applied to a variable capacity type compressor will now be explained with reference to FIGS. **1A** to **5**.

Referring to FIG. **5**, a front housing **12** is coupled to the front end of a cylinder block **11**, and a rear housing **13** is fixed to the rear end of the cylinder block **11** via a partition plate **14**, valve-forming plates **15** and **16** and a retainer-forming plate **17**. A drive shaft **18** is rotatably supported by the front housing **12** and the cylinder block **11** which together form a control pressure chamber **121**. The drive shaft **18** protruding outward from the control pressure chamber **121** receives a driving force from an external driving source such as a car engine (not shown) through a pulley (not shown) and a belt (not shown).

A rotation support member **19** is anchored to the drive shaft **18**. The drive shaft **18** supports a swash plate **20** in such a fashion that the swash plate **20** can slide in an axial direction with respect to the drive shaft **18** and can incline. The swash plate **20** can incline with respect to the axis of the drive shaft **18** and can rotate with the drive shaft **18**, by the cooperation of a pair of guide pins **21** fixed to the swash plate **20** and a pair of guide holes **191** in the rotation support member **19**. The inclination movement of the swash plate **20** is guided by the slide guide relation between the guide hole **191** and the guide pin **21** as well as the slide support operation of the drive shaft **18**.

When the radial center portion of the swash plate **20** moves towards the rotation support member **19**, the angle of inclination of the swash plate **20** increases. When the radial center portion of the swash plate **20** moves towards the cylinder block **11**, the angle of inclination of the swash plate decreases. The minimum angle of inclination of the swash plate **20** is defined by the abutment of a circlip **22** fitted to the drive shaft **18** against the swash plate **20**. The maximum angle of inclination of the swash plate **20** is defined by the abutment of the rotary support member **19** against the swash plate **20**. The position of the swash plate **20** indicated by the solid line represents the position of the minimum angle of inclination of the swash plate **20**. The position of the swash plate **20** indicated by the chain line represents the position of the maximum angle of inclination of the swash plate **20**.

As shown in FIG. **1A**, a plurality of cylinder bores **111** (five, in this embodiment) are formed in the cylinder block **11**. The cylinder bores **111** are disposed equidistantly about the drive shaft **18**. Pistons **23** are arranged in the cylinder bores **111**, as shown in FIG. **5**. The rotating motion of the swash plate **20** is converted into the reciprocating motion of the pistons **23** through shoes **24**, and the pistons **23** move back and forth in the cylinder bores **111**.

A suction chamber **131** and a discharge chamber **132** are defined in the rear housing **13**. The discharge chamber **132** surrounds the suction chamber **131** through a partition wall **133**. A supply passage **25** is arranged in the rear wall of the rear housing **13**.

As shown in FIGS. **2** and **5**, suction ports **26** are formed in the partition plate **14**, the valve-forming plate **16** and the retainer-forming plate **17** corresponding to the cylinder bores **111**. Discharge ports **27** are formed in the partition plate **14** at positions corresponding to cylinder bores **111**. Suction valves **42** are formed in the valve-forming plate **15**, and discharge valves **161** are formed in the valve-forming plate **16**. Each of the suction valves **42** and the discharge valves **161** is integral with the associated valve-forming plate, and is thus fixed at its proximal end to the valve-forming plate while the substantial part thereof is flexible. A window **421** is formed in the proximal end portion of the suction valve **42** corresponding to the discharge port **27**. The distal end portion of the suction valve **42**, that undergoes flexural deformation, comes into, and out from, contact with the contact surface **141** of the partition plate **14** on the one side thereof and opens and closes the suction port **26**. The distal end portion of the discharge valve **161**, that undergoes flexural deformation, comes into, and out from, contact with the contact surface **142** of the partition plate **14** on the other side thereof and opens and closes the discharge port **27**.

As shown in FIGS. **1B** and **2**, a maximum opening limiting recess **28** is formed in each cylinder bore **111**. The maximum opening limiting recess **28** has a side surface **281** and a bottom surface **282**. The side surface **281** of the maximum opening limiting recess **28** is a circular circumferential surface. An engaging projection **422** having a semi-circular arcuate shape is formed at the distal end of the suction valve **42**. As shown in FIG. **2**, the engaging projection **422** can abut against the bottom surface **282** of the maximum opening limiting recess **28**, and the maximum opening limiting recess **28** defines the maximum opening of the suction valve **42**. FIG. **3** shows the maximum opening condition of the suction valve **42**.

A refrigerant gas in the suction chamber **131** is sucked through the suction port **26** into the cylinder bore **111**, pushing the suction valve **42**, during the returning movement (movement from the right to the left in FIG. **5**) of the piston **23**. The refrigerant gas in the cylinder bore **111** is discharged through the discharge port **27** into the discharge chamber **132**, pushing the discharge valve **161** during the forward movement (movement from the left to the right in FIG. **5**) of the piston **23**. As the discharge valve **161** comes into contact with the retainer **171** on the retainer-forming plate **17**, its opening is restricted. The coolant discharged into the discharge chamber **132** is fed to a condenser **30**, an expansion valve **31** and an evaporator **32** on an external refrigerant circuit **29** outside the compressor and returned to the suction chamber **131** from the supply passage **25**.

A solenoid-operated capacity control valve **34** is arranged in a pressure feed passage **33** (shown in FIG. **1A**) that connects the discharge chamber **132** to a control pressure chamber **121**. The pressure feed passage **33** supplies the refrigerant gas in the discharge chamber **132** to the control pressure chamber **121**. The solenoid-operated capacity control valve **34** is activated and inactivated by a controller (not shown), which controls activation and deactivation of the solenoid-operated capacity control valve **34** based on a detected compartment temperature detected by a compartment temperature sensor (not shown) detecting a compartment temperature of the car and a target compartment temperature set by a compartment temperature setter (not shown).

The refrigerant gas in the control pressure chamber **121** flows out to the suction chamber **131** through a pressure release passage **35** (shown in FIG. **1A**). When the solenoid-operated capacity control valve **34** is in the deactivated condition, the refrigerant gas in the discharge chamber **132** is not delivered to the control pressure chamber **121**. Therefore, the pressure difference between the control pressure in the control pressure chamber **121** and the suction pressure on opposite sides of the piston **23** becomes smaller, and the inclination angle of the swash plate **20** shifts towards the maximum angle side. When the solenoid-operated capacity control valve **34** is in the activated state, the refrigerant gas in the discharge chamber **132** is delivered to the control pressure chamber **121** through the pressure feed passage **33**. Therefore, the pressure difference between the control pressure in the control pressure chamber **121** and the suction pressure on the opposite sides of the piston **23** becomes greater and the inclination angle of the swash plate **20** shifts to the minimum angle side.

FIG. **4** shows the valve closing condition where the suction valve **42** closes the suction port **26**. The suction port **26** is formed in the shape similar to a sector with an apex portion of the sector removed. A contour line of the suction port **26** positioned on the contact surface **141** of the partition plate **14** includes a proximal end line **36** positioned on the side of the proximal end of the suction valve **42** (on the side of the window **421**), a distal end line **37** positioned on the side of the distal end of the suction valve **42**, a pair of right and left side lines **39** and **38**, a first connection line **401** that interconnects the proximal end line **36** and the side line **38**, another first connection line **402** that interconnects the proximal end line **36** and the side line **39**, a second connection line **411** that interconnects the distal end line **37** and the side line **38**, and another second connection line **412** that interconnects the distal end line **37** and the side line **39**. The suction valve **42** has a symmetric shape with respect to a reference line X extending in the longitudinal direction of the suction valve **42**, and the suction port **26** has a symmetric shape with respect to the reference line X. In other words, the left and right portions of the suction valve **42** and the suction port **26** are symmetric.

The proximal end line **36** is a convex curve slightly protruding from the distal end side of the suction valve **42** toward the proximal end side of the suction valve **42**. The distal end line **37** is a convex curve protruding from the proximal end side of the suction valve **42** toward the distal end side of the suction valve. The side lines **38** and **39** are approximately straight lines extending substantially along the radial line r**3** of the circle C associated with the circumferential surface **112** of the cylinder bore **111**. The first connection line **401** is a curve smoothly connected to the proximal end line **36** and the side line **38** at positions L1 and L2, and another first connection line **402** is a curve smoothly connected to the proximal end line **36** and the side line **39** at positions R_1 and R_2. The second connection line **411** is a curve smoothly connected to the distal end line **37** and the side line **38** at positions L3 and L4, and another second connection line **412** is a curve smoothly connected to the distal end line **37** and the side line **39** at positions R3 and R4.

The bending angle θ2 of the second connection lines **411** and **412** is greater than the bending angle θ1 of the first connection lines **401** and **402**. The bending angle θ1 represents an angle formed by normal lines m**1** and m**2** at the positions L1 and L2 and an angle formed by normal lines n**1** and n**2** at the positions R1 and R2. The bending angle θ2 represents an angle formed by normal lines m**3** and m**4** at positions L3 and L4 and an angle formed by normal lines n**3** and n**4** at positions R3 and R4.

In this embodiment, each of the proximal end line **36**, the distal end line **37**, the first connection lines **401** and **402** and the second connection lines **411** and **412** comprises a circular arc. The radius of curvature of the proximal end line **36** is greater than that of the distal end line **37**.

As shown in FIGS. **1**B and **4**, the distal end portion of the suction valve **42** comprises an outer contour line extending along the distal end line **37**, the second connection lines **411** and **412** and the side lines **38** and **39** of the suction port **26**. The outer contour line of the distal end portion of the suction valve **42** comprises an arcuate engaging line **43** defining the outer profile of the engaging protrusion **422**, a pair of right and left distal end forming lines **44** and **45**, a pair of right and left side lines **46** and **47**, a connection line **48** interconnecting the distal end forming line **44** and the side line **46**, and a connection line **49** interconnecting the distal end line forming line **45** and the side line **47**.

As shown in FIG. **4**, the distal end forming lines **44** and **45** comprise an arcuate curve that is concentric with the arcuate distal end line **37** of the suction port **26**. That is, the distance between the distal end line **37** of the suction port **26** and the distal end forming lines **44** and **45** of the suction valve **42** with respect to the direction of the arcuate radial lines r**1** and r**2** of the arcuate distal end line **37** and the distal end forming lines **44** and **45** is constant. The distance α between the distal end line **37** of the suction port **26** and the distal end forming lines **44** and **45** of the suction valve **42** with respect to the direction of the radial line r**3** of the circle C of the cylinder bore **11** is not constant. However, the change of the gap α is only slight and is therefore substantially constant.

The side line **46** is a straight line parallel to the side line **38** of the suction port **26**, and the side line **47** is a straight line parallel to the side line **39** of the suction port **26**. The connection line **48** is an arcuate curve concentric with the arcuate second connection line **411** of the suction port **26**. The connection line **49** is an arcuate curve concentric with the arcuate second connection line **412** of the suction port **26**. The connection line **48** is a curve connected smoothly to the distal end forming line **44** and the side line **46** at positions Y1 and Y2. The connection line **49** is a curve connected smoothly to the distal end forming line **45** and the side line **47** at positions Z1 and Z2.

The radius of curvature of the arcuate distal end line **37** is slightly smaller than the radius of the circle C of the cylinder bore **111**. The arc center **374** of the distal end forming lines **44** and **45** of the suction valve **42** is slightly shifted from the center Co of the circle C of the cylinder bore **111** towards the distal end of the suction valve **42** along the reference line X. Therefore, the gap β between the distal end forming lines **44**, **45** of the suction valve **42** and the circle C of the cylinder bore **111** (the gap in the direction of the radial line r**3** of the circle C of the cylinder bore **111**) is not constant, but the change of the gap β is slight and the gap β is substantially constant.

The average of the gap β is greater than the gap γ (shown in FIG. **2**) between the suction valve **42** and the distal end line **37** of the suction port **26** under the maximum valve open state.

The refrigerant gas passing through the suction port **26** from the side of the suction chamber **131** towards the side of the cylinder bore **111** flows between the contact surface **141** of the partition plate **14** and the suction valve **42** in the direction of the normal lines to the outer contour line of the suction port **26** or the contact surface **141** (the normal lines being represented by arrows N1, N2, N3 and N4 in FIG. **1**B). The refrigerant gas flowing between the contact surface **141** and the suction valve **42** in the direction of the normal lines N2, N3 and N4 then flows from between the outer contour line of the suction valve **42** and the contact surface **141** towards the circumferential surface **112** of the cylinder bore **111**. The refrigerant gas flowing between the contact surface **141** and the suction valve **42** in the direction of the normal line N1 then flows towards the window **421**.

The first embodiment provides the following effects.

(1-1) The refrigerant gas flowing towards the distal end forming lines **44** and **45** in the direction of the normal line N2 then flows in the returning direction of the piston **23** from between the distal end forming lines **44** and **45** and the circumferential surface **112** of the cylinder bore **111**. The distance α between the distal end forming lines **44** and **45** of the suction valve **42** and the distal end line **37** of the suction port **26** is substantially constant, and the distance β between the distal end forming lines **44** and **45** and the circumferential surface **112** of the cylinder bore **111** is substantially constant. In other words, the distance (α+β) between the distal end **37** of the suction port **26** and the circumferential surface **112** of the cylinder bore **111** in the direction of the radial line r**2** is substantially constant. Therefore, according to the construction in which the distances α and β are substantially constant, the refrigerant gas flowing towards the circumferential surface **112** from between the suction valve **42** and the distal end line **37** of the suction port **26** is apt to impinge perpendicularly against the circumferential surface **112**.

The gas flowing from between the suction valve **42** and the distal end line **37** of the suction port **26** towards the circumferential surface **112** of the cylinder bore **111** so as to perpendicularly impinge against the circumferential surface **112** is apt to flow from between the circumferential surface **112** of the cylinder bore **111** and the distal end forming lines **44** and **45** of the suction valve **42** in the returning direction of the piston **23** (in the direction from the right to the left in FIG. **5**). That is, the refrigerant gas flowing in the direction perpendicular to the contour line of the suction port **26** close to the circumferential surface **112** of the cylinder bore **111** (the distal end line **37**) is not apt to flow in the circumferential direction of the circumferential surface **112** of the cylinder bore **111**. The suction port **26** and the suction valve **42** providing such a flow of the refrigerant gas improves easiness of the inflow of the cooling gas into the cylinder bore **111** and also improves compressor performance.

(1-2) The radius r**4** of the arcuate engaging line **43** is smaller than the arcuate radius r**5** of the circumferential side surface **281** of the maximum opening limiting recess **28**, so that the distance between the engaging line **43** and the arc Ac of the side surface **281** at both ends thereof is great. Therefore, the refrigerant gas flowing towards the engaging line **43** of the engaging projection **422** in the direction of the normal line N**2** can flow more easily between the end portions of the engaging line **43** and the end portions of the arc Ac of the side surface **281** in the returning direction of the piston **23**. Such a flow of the refrigerant gas contributes to an improvement in the ease of the inflow of the refrigerant gas into the cylinder bore **111**.

(1-3) As shown in FIG. **4**, the suction port **26** is offset from the center Co of the circle C of the circumferential surface **112** of the cylinder bore **111**. Two radial lines r**31** and r**32** of the radial lines r**3** of the circle C of the circumferential surface **112** of the cylinder bore **111** are tangential to the outer contour line of the suction port **26**, and form a predetermined angle ω with respect to the center Co of the circle C. The curve K in FIG. **4** is a part (arc) of a reference circle concentric with the circle C, and ro is one of the radial lines of the reference circle K. The reference circle K crosses the connection lines **48** and **49**, but most part of the reference circle K exists between the contour line of the suction port **26** and the outer contour line of the suction valve **42** within the range of angle ω. Moreover, the reference circle K does not cross the distal end line **37** and the distal end forming lines **44** and **45**. The arrangement in which most of the arc of the reference circle K, which passes between the distal end line **37** and the distal end forming lines **44** and **45** and is concentric with the circuit C, falls between the contour line of the suction port **26** and the outer contour line of the suction valve **42**, provides a substantially constant gap α and a substantially constant gap β. The suction port **25** and the suction valve **42** that have substantially constant gaps α and β improve the ease of the inflow of the refrigerant gas into the cylinder bore **111**.

(1-4) The average of the gap β between the circumferential surface **112** of the cylinder bore **111** and the distal end forming lines **44** and **45** of the suction valve **42** is greater than the gap γ between the suction valve **42** under the maximum valve opening condition and the distal end line **37** of the suction port **26**. The portion of the gap γ between the suction valve **42** and the distal end line **37** is located on the upstream side of the portion of the gap β between the circumferential surface **112** of the cylinder bore **111** and the distal end forming lines **44** and **45** of the suction valve **42**, with respect to the flow of the refrigerant gas. The construction in which the average of the gap β of the cooling gas passage portion located on the downstream side of the portion of the gap γ is greater than the distance γ makes it easy for the gas flowing perpendicularly impinge against the circumferential surface **112** of the cylinder bore **111** to flow in the returning direction of the piston **23**.

(1-5) The area S encompassed by the proximal end line **36**, the distal end line **37**, the side lines **38** and **39** and the connection lines **401**, **402**, **411** and **412** is the flow sectional area of the suction port **26**. When the suction port **26** is viewed in the reciprocating direction of the piston **23**, a middle line T shown in FIG. **4** passes through the middle point Ho of the maximum length (represented by H in FIG. **4**) of the suction port **26** in the longitudinal direction of the suction valve **42** (that is, in the direction of the reference line X), extends transversely with respect to the suction port **26**, and perpendicularly crosses the reference line X extending in the longitudinal direction of the suction valve **42**. When the suction port **26** is viewed in the reciprocating direction of the piston **23**, the middle line T assumed in this way divides the suction port **26** into first and second sections **261** and **262**. The area S**2** of the second section **262** positioned on the distal end side of the suction valve **42** is greater than the area S**1** of the first section **261**. The greater the area S**2** of the second section **262** is than the area S**1** of the first section **261**, the greater is the length of the contour line of the suction port **26** on the distal end side of the suction valve **42**. In other words, the more the center of gravity of the area of the suction port **26** is shifted towards the distal end side of the suction valve **42**, the greater is the length of the contour line of the suction port **26** on the distal end side of the suction valve **42**.

The opening gap γ of the suction valve **42** relative to the partition plate **14** becomes greater towards the distal end of the suction valve **42**, as shown in FIG. **2**. Therefore, the greater the ratio of a portion of the refrigerant gas passing through the suction port **26** on the distal end side of the suction valve **42** is relative to a portion of the refrigerant gas passing through the suction port **26** on the proximal end side thereof, the higher is the degree of improvement in the easy inflow of the refrigerant gas into the cylinder bore **111** from the suction chamber **131**. The longer the length of the contour line of the suction port **26** on the distal end side of the suction valve **42** is, the greater is the proportion of the flow of the refrigerant gas passing through the suction port **26** on the distal end side thereof relative to that on the proximal end side of the suction valve **42**. Therefore, the construction in which the area S**2** of the second section **262** is greater than the area S**1** of the first section **261** enables the gas to more easily flow through the suction port **26** between the suction valve **42** on the distal end side of the suction valve **42** and the contact surface **141**. As a result, the ease of inflow of the refrigerant gas when the refrigerant gas is sucked from the suction port **26** into the cylinder bore **111** can be improved, and the performance of the compressor can also be improved.

(1-6) The width of the suction port **26** (represented by W in FIG. **4**) measured in the direction of the middle line T becomes gradually greater in the longitudinal direction of the suction valve **42** (in the direction of the reference line X) from the proximal end side to the distal end side of the suction valve **42**, within the range D shown in FIG. **4**. The region Do of the suction port **26** (hatched with chain hatching lines in FIG. **4**) within the range D is a width increasing region where the width W becomes gradually greater in the direction of the reference line X from the proximal end side to the distal end side of the suction valve **42**. The length d of the width increasing region Do in the direction of the reference line occupies a major part of the maximum length H of the suction port **26** in the direction of the reference line X. The existence of such a width increasing region Do is convenient for making the area S2 of the second section **262** greater than the area S1 of the first section **261**, and the length of the contour line of the suction port **26** can be easily elongated as the width increasing region Do is disposed. Therefore, the existence of the width increasing region Do allows the refrigerant gas passing through the suction port **26** to more easily flow between the suction valve **42** and the contact surface **141** on the distal end side of the suction valve **42**.

(1-7) The maximum width of the suction port **26** (represented by Wo in FIG. **4**) in the direction of the middle line T exists in the second section **262**. This maximum width Wo is greater than the maximum length H of the suction port **26** in the direction of the reference line X. The construction in which the maximum length H of the suction port **26** in the direction of the reference line X is smaller than the maximum width Wo of the suction port **26** in the direction of the middle line T is more advantageous for elongating the contour line of the suction port **26** on the distal end side of the suction valve **42** than the case where H>Wo. The closer the position of the maximum width Wo of the suction port **26** to the distal end of the suction valve **42**, the more advantages it becomes to elongate the contour line of the suction port **26** on the distal end side of the suction valve **42**. In other words, the construction in which the maximum length H of the suction port **26** in the direction of the reference line X is smaller than the maximum width Wo of the suction port **26** in the direction of the middle line T and the maximum width Wo exists in the second section **262** is convenient for elongating the length of the contour line of the suction port **26** on the distal end side of the suction valve **42**.

(1-8) The distal end line **37** is longer than the proximal end line **36**. The construction in which the distal end line **37** is longer than the proximal end line **36** enables the refrigerant gas passing through the suction port **26** to more easily flow towards the distal end side of the suction valve **42**.

(1-9) The closer the distal end line **37** is to the circle C of the circumferential surface **112** of the cylinder bore **111**, the greater is the opened gap γ between the distal end line **37** and the suction valve **42** under the valve open condition. The greater the gap γ is between the distal end line **37** and the suction valve **42**, the easier it becomes for the refrigerant gas to flow into the cylinder bore **111**. The distal end line **37** is an arc protruding outward from the proximal end side to the distal end side of the suction valve **42**. The radius of curvature of the distal end line **37** is slightly smaller than the radius of the circle C of the circumferential surface **112** of the cylinder bore **111**. The construction in which the distal end line **37** is the convex curve approximate to the circle C of the circumferential surface **112** of the cylinder bore **111** is advantageous for bringing the distal end line **37** closer to the circle C of the circumferential surface **112** of the cylinder bore **111**.

(1-10) The pressure in the cylinder bore **111** urges the suction valve **42** against the periphery wall of the suction port **26**, in the condition where the refrigerant gas in the cylinder bore **111** is discharged to the discharge chamber **132**, and the suction valve **42** closes the suction port **26**. In conjunction with the contour line of the suction port **26**, the smaller the length of the contour line in the unit area, the more it becomes difficult for the refrigerant gas to leak from the cylinder bore **111** to the suction port **26** through the gap between the contact surface **141** and the suction valve **42**. Supposing that a corner exists at a part of the contour line of the suction port **26**, however, the length of the contour line in the unit area in the proximity of this corner becomes large. Therefore, the construction in which the corner exists at a part of the contour line of the suction port **26** is likely to invite the backflow of the refrigerant gas from the cylinder bore **111** to the suction port **26**. The backflow of the refrigerant gas invites a drop in volumetric efficiency. The contour line of the suction port **26** comprising the proximal end line **36**, the distal end line **37**, the side lines **38** and **39**, the first connection lines **401** and **402** and the second connection lines **411** and **412** becomes an annular line without any corner. The construction in which the contour line of the suction port **26** is an annular line without any corner is advantageous for preventing the refrigerant gas from back-flowing from the cylinder bore **111** to the suction port **26**.

(1-11) The bending angle θ2 of the second connection lines **411** and **412** is greater than the bending angle θ1 of the first connection lines **401** and **402**. Unless the shapes of the proximal end line **36**, the distal end line **37** and the side lines **38** and **39** change greatly, the length of the distal end line **37** becomes progressively greater as the bending angle θ2 becomes progressively greater than the bending angle θ1. The construction in which the bending angle θ2 of the second connection lines **411** and **412** is greater than the bending angle θ1 of the first connection lines **401** and **402** is convenient as a construction for increasing the length of the distal end line **37**.

(1-12) The closer the contour line of the suction port **26** on the distal end side of the suction valve **42** is to the circumferential surface **112** of the cylinder bore **111**, the easier it becomes for the refrigerant gas to flow into the cylinder bore **111**. Normally, the shapes of the suction valve **42** and the suction port **26** are set to symmetric shapes with respect to the reference line X, respectively. Then, the contour line of the suction port **26** on the distal end side of the suction valve **42** becomes symmetric with respect to the reference line X. When the distal end line **37**, which is symmetric with the reference line X, is brought closer to the circumferential surface **112** of the cylinder bore **111** along the reference line X, the distal end line **37** can be brought most closely to the circumferential surface **112** of the cylinder bore **111** when the reference line X is in conformity with the radial line r**3** of the circle C of the circumferential surface **112** of the cylinder bore **111**. Therefore, the construction in which the reference line X is allowed to extend substantially along the radial line r**3** of the circle C of the circumferential surface **112** of the cylinder bore **111** is advantageous for bringing the distal end line **37** closer to the circle C of the circumferential surface **112** of the cylinder bore **111**.

(1-13) In the piston compressor, self-induced vibration may possibly occur during the shift of the suction valve from the position in which it closes the suction port to the maximum opening position, and this self-induced vibration invites suction pulsation. Suction pulsation causes the evaporator **32** in the external coolant circuit **29** to vibrate and to generate noise. In the variable capacity type compressor having the pistons **23**, the pistons **23** reciprocate with strokes corresponding to the angle of inclination of the tiltable swash plate **20** so that the capacity becomes small when the angle of inclination of the swash plate **20** becomes small. The average gas flow rate through the suction ports is small under the low capacity condition, and the suction valves may not abut against the bottom surfaces **282** of the maximum opening limiting recesses **28**. In consequence, self-induced vibration of the suction valve is likely to occur in the variable capacity type compressor.

In the construction in which the area S2 of the second section **262** is greater than the area S1 of the first section **261**, the flow of the refrigerant gas flowing from the suction chamber **131** into the cylinder bore **111** is likely to more greatly concentrate on the distal end side remote from the proximal end of the suction valve **42**, compared with the case of a suction port such as the one described in Japanese Unexamined Patent Publication (Kokai) No. 2000-54961, for example. Therefore, the suction valve **42** may abut against the bottom surface **282** of the maximum opening limiting recess **28** even under the low capacity condition, and self-induced vibration of the suction valve **42** will be less likely to occur.

Next, the second embodiment of the present invention will be explained with reference to FIGS. **6**A and **6**B, in which like reference numerals are used to identify like elements in the first embodiment.

The contour line of the suction port **26**A comprises the proximal end line **36**, the distal end line **37**, the curved side lines **38**A and **39**A, the first connection lines **401**A and **402**A, and the second connection lines **411**A and **412**A. The radius of curvature of each of the first and second connection lines **401**A, **402**A, **411**A, and **412**A is greater than the radius of curvature of the first connection lines **401** and **402** in the first embodiment. The contour line of such a suction port **26**A is an annular line having no corner and no straight line. The outer contour line of the suction valve **42**A on the distal end portion thereof comprises the engaging line **43**, a pair of right and left distal end forming lines **44** and **45**, a pair of right and left arcuate side lines **46**A and **47**A, the arcuate connection line **48**A interconnecting the distal end forming line **44** and the side line **46**, and the arcuate connection line **49**A interconnecting the distal end line **45** and the side line **47**A. The radius of curvature of the connection lines **48**A and **49**A is greater than the radius of curvature of the connection lines **48** and **49** in the first embodiment. The outer contour line of such a suction valve **42**A on the distal end portion thereof is a line having no corner and no straight line.

The construction in which the contour line of the suction port **26**A is an annular line having no corner and no straight line and the outer contour line of the suction valve **42**A on the distal end portion thereof is a line having no corner and no straight line provides the same effect as that of the first embodiment. The construction in which the radius of curvature of the connection lines **401**A, **402**A, **411**A and **412**A is greater than the radius of curvature of the connection lines **401** and **402** in the first embodiment is much more advantageous than the first embodiment for preventing the refrigerant gas from back-flowing from the cylinder bore **111** to the suction port **26**A.

FIG. **7** shows the third embodiment and FIG. **8** shows the fourth embodiment. FIG. **9** shows the fifth embodiment and FIG. **10** shows the sixth embodiment. Like reference numerals are used in these drawings to identify like elements in the first and second embodiments.

The proximal end line **36**B of the suction port **26**B shown in FIG. **7** is a concave curve recessed from the proximal end side to the distal end side of the suction valve **42**A.

The distal end line **37**C of the suction port **26**C shown in FIG. **8** is a part of an ellipse. The distal end line **37**C and a pair of side lines **38**A and **39**A are smoothly connected at positions L**5** and R**5**. Reference numerals **44**C and **45**C denote distal end forming lines of the suction valve **42**C.

The proximal end line **36**D of the suction port **26**D shown in FIG. **9** is a part of a circle and the distal end line **37**D is a part of an ellipse. The proximal end line **36**D and the distal end line **37**D are connected smoothly at positions L**6** and R**6**. Reference numerals **44**D and **45**D denote the distal end forming lines of the suction valve **42**D.

The suction port **26**E shown in FIG. **10** represents the shape formed by inverting the suction port described in Japanese Unexamined Patent Publication (Kokai) No. 2000-54961 in the direction of the reference line X. The proximal end line **36**E of the suction port **26**E is smoothly connected to a pair of connection lines **411**A and **412**A. Reference numerals **44**E and **45**E denote the distal end forming lines of the suction valve **42**E.

The distal end line **37**F of the suction port **26**F in FIG. **11** comprises a first distal end line **371**, a second distal end line **372** and a connection line **373**. The connection line **373** is smoothly connected to the first distal end line **371** and the second distal end line **372** at positions L**7** and R**7**. Reference numerals **44**F and **45**F denote the distal end forming lines of the suction valve **42**F.

The distal end line **37**G of the suction port **26**G shown in FIG. **12** is a part of a circle, and the proximal end line **36**G is a part of an ellipse. The distal end line **37**G and the proximal end line **36**G are smoothly connected at positions L**8** and R**8**. Reference numerals **44**G and **45**G denote the distal end forming lines of the suction valve **42**G.

The distal end lines **37**, **37**C, **37**D, **37**F and **37**G of the suction ports **26**B, **26**C, **26**D, **26**E, **26**F and **26**G in the embodiments shown in FIGS. **7** to **12** and the distal end forming lines **44**, **45**, **44**C, **45**C, **44**D, **45**D, **44**E, **45**E, **44**F, **45**F, **44**G and **45**G of the suction valves **42**, **42**A, **42**C, **42**D, **42**E and **42**F have the same relationship with the first embodiment regarding the distances α, β and γ and the reference circle K. The forming lines of the suction ports **26**B to **26**F in the embodiments shown in FIGS. **7** to **11** provide the same condition as the suction port **26** of the first embodiment as to the size of the first and second areas S**1** and S**2** of the first and second section ranges **261** and **262**, the length relationship of the maximum length H and the width Wo and the relationship of the length d of the width increasing region Do and the maximum length H.

Incidentally, the present invention can also be applied to suction ports having an asymmetric shape with respect to the reference line. The shape of the engaging line of the suction valve is not limited to the circular arc but may have an arbitrary convex shape.

As described above in detail, in the present invention, the outer contour line of the distal end portion of the suction valve and the contour line of the distal end portion of the suction port are disposed to extend along the circle of the circumferential surface of the cylinder bore, the gap between the distal end outer contour line of the suction valve and the distal end contour line of the suction port in the direction of the radial line of the circle of the outer circumferential surface of the cylinder bore is kept substantially constant, and the gap between the distal end outer contour line of the suction valve and the circumferential surface of the cylinder bore in the direction of the radial line is kept substantially constant. Therefore, the present invention provides the excellent effect in which facility of the inflow of the gas (lack of resistance of inflow to the gas) can be improved when the gas is sucked from the suction port to the cylinder bore.

What is claimed is:

1. A piston type compressor comprising:

a housing having cylinder bores, a suction chamber, a discharge chamber, suction ports and discharge ports formed therein;

pistons reciprocatingly arranged in said cylinder bores;

a drive shaft rotatably supported by said housing;

a transmission mechanism operatively coupled to said drive shaft and said pistons for converting rotation of said drive shaft into reciprocal movement of the pistons;

suction valves to open and close the suction ports;

discharge valves to open and close the discharge ports;

wherein each said suction valve has a proximal end portion and a distal end portion on the opposite side of the proximal end portion, said distal end portion of said suction valve having an outer contour line including a distal end forming line located near a circumferential surface of said cylinder bore and side lines located on either side of said distal end forming line, each said suction port having a contour line including a distal end line located near the circumferential surface of the cylinder bore and side lines located on either side of said distal end line; and

said distal end forming line of said suction valve and said distal end line of said suction port being arranged along said circumferential surface of said cylinder bore, so that a gap between said distal end forming line and said distal end line with respect to a radial line of a circle forming the circumferential surface of the cylinder bore is substantially constant and a gap between said distal end forming line and said circumferential surface of said cylinder bore with respect to said radial line is substantially constant.

2. A piston type compressor according to claim **1**, wherein an average of said gap between the circumferential surface of said cylinder bore and said outer end forming line of said suction valve is greater than a gap between said suction valve and said distal end line of said suction port under a maximum valve open condition.

3. A piston type compressor according to claim **2**, wherein a middle line is provided which passes through a middle point of a maximum length of said suction port in a longitudinal direction of said suction valve, extends transversely with respect to said suction port and perpendicularly crosses a reference line extending in the longitudinal direction of said suction valve, said middle line dividing said suction port into a first section positioned on the side of the proximal end of said suction valve and a second section positioned on the side of said distal end of said suction valve, an area of said second section being greater than an area of said first section.

4. A piston type compressor according to claim **3**, wherein a width increasing region is disposed in which the width of said suction port in a direction of said middle line becomes gradually greater from the proximal end side to the distal end side of said suction valve in the longitudinal direction of said suction valve, and the length of said width increasing region in the direction of said reference line occupies a major part of the maximum length of said suction port in the direction of said reference line.

5. A piston type compressor according to claim **4**, wherein a maximum width of said suction port in the direction of said middle line exists in said second section and is greater than a maximum length of said suction port in the direction of said reference line.

6. A piston type compressor according to claim **3**, wherein the contour line of said suction port includes a proximal end line positioned on the side of the proximal end of said suction valve, said distal end line, and a pair of right and left side lines, and said distal end line is longer than said proximal end line.

7. A piston type compressor according to claim **6**, wherein said contour line of said suction port includes a pair of first connection lines connecting said proximal end line to said pair of side lines, and a pair of second connection lines connecting said distal end line to said pair of side lines, said pair of first connection lines being smoothly connected to said proximal end line and said pair of said side lines, said pair of second connection lines being smoothly connected to said distal end line and said pair of side lines.

8. A piston type compressor according to claim **1**, wherein said contour line of said suction port is an annular convex curve with no corner.

9. A piston type compressor according to claim **3**, wherein said reference line extends substantially along the radial line of the circle of the circumferential surface of said cylinder bore.

10. A piston type compressor according to claim **1**, wherein the suction port is formed in the shape of a portion of a sector with an apex portion of a sector removed.

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